# Enhancing the Vacuum Assisted Resin Transfer Molding (VARTM) Process Through the Alteration of Variables

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# Abstract

This report documents how process alteration greatly affects the outcome of a composite material panel when using VARTM. An instrument is used to calculate and record the change in thickness in the composite piece during infusion.

# Introduction

Composites are fibrous materials infused with a tough and durable plastic. Composite material is a technology that is being used to make many items in today's world stronger and lighter. These materials are starting to be incorporated into the armor of combat vehicles and soldiers. When these panels are made in the most economical way, they are inferior to those that take much more time and money to construct. Developing a method that is fast and reliable is critical. A controlled setup must be designed in order to get optimized infusion. The experimental process in which infusion is accomplished is called Vacuum Assisted Resin Transfer Molding (VARTM). In this process a vacuum pulls resin in from a feed tube to distribute it evenly into the preform.

# Body

There are several different steps that must be followed in order to run a VARTM infusion. A selection of materials that will be infused must be acquired. For example, twenty-four plies of glass and eleven plies of IM7 graphite are stacked onto each other with the IM7 on the bottom. This creates the preform that will be infused. Another option for materials is a preform piece, manufactured by a company called Solectria, which is held together by a binder.

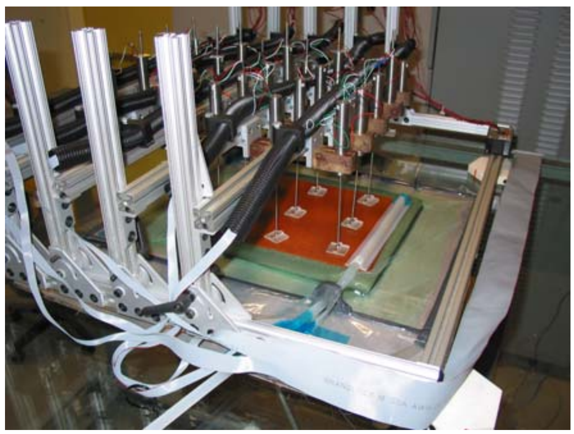
The preform is placed on a steel plate that has already been coated with several layers of Frekote. Frekote is a substance that deters two substances from bonding together. This is important so that the finished panel does not stick to the steel plate and is easily accessible. To also help this, a sheet of peel ply is placed between the preform and the plate. The peel ply is a highly permeable fabric allowing resin to flow through it, but not hardening with the preform. When the process is finished, the peel ply allows the preform to have a uniform texture. The next step is to place another sheet of peel ply on top of the glass, so the vacuum bag does not stick to the finished composite panel. A layer of SCRIMP (Seemann Composite Resin Infusion Molding Process) distribution medium is positioned on the glass. This enables the resin to travel at a higher pace so that it creates a sharper driving force to introduce resin into the preform.

Tacky tape forms the perimeter around the entire preform. It is placed about two to three inches wider than the preform to give room for tubing and bagging. A piece of tubing, which has been cut in a spiral shape, is placed at the back of the preform. Another piece of tubing, which is connected to the vacuum pot, is inserted into the coiled tubing. The vacuum pot is a sealed bucket that collects any excess resin that comes out of the preform. This is important because the vacuum pump would be ruined if resin enters the vacuum line. A feed line is then installed at the front of the piece. Another piece of coiled tubing works well for preforms and an omega channel works better for the pieces made by Solectria. These lines are made airtight by wrapping tacky tape around the edges that cross the previously made tacky tape perimeter.

The final step in the setup is the addition of the vacuum bag. The bag is adhered to the tacky tape and positioned around the tubes. When there is excess bag in an area, an "ear" is formed with tacky tape to guarantee that the bag will be airtight. This is a crucial step because any small holes could cause loss of a full vacuum.

Once the entire setup is complete, a vacuum check is made. Before starting the infusion, a piece of equipment that measures the change in thickness is situated on top of the piece.

The device that measures the change in thickness is called Linear Variable Differential Transducer (LVDT) array. There are many sensors located on the LVDT array in stationary positions (fig. 1). Each sensor has a “foot” that touches the piece. The sensors are magnetic coils; if the position of the sensor rod changes, the voltage from the sensors will be detected and sent to a computer, where the resistance is converted to distance in inches. When the piece changes thickness during the infusion, the feet rise and the sensors detect the change.



**<u>Figure 1</u>-** LVDT positioned on a Solectria preform

The computer records the data and constructs a graph of the changing thickness vs. time. When completed, the graph can be viewed in its entirety to show the behavior of the piece when the resin passed through. These graphs are analyzed to determine the best way to infuse the pieces.

Numerous factors in the setup process can modify the desired final product. A correct bagging job is one that is not too tight and has no leaks or creases. A bag that is too tight could leave channels running on the sides of the preform, causing the resin to move around the piece on the sides rather than through the preform.

This occurs because fluids travel through the path of least resistance. Most of the resin will follow in these voids and leave through the vacuum tube. Only some resin will enter the piece, making dry spots and weakening the composite.

When fabricating the Solectria panels, a very loose bag was required so that the bag would fit tightly into the corners to eliminate race tracking and to stop dry spots from occurring. Any tension on the bag would open a channel for the resin to travel through.

Another variable is the time needed to perform an infusion. There were a total of thirty-three plies of glass and graphite infused at once. The time needed to wet-out all the plies is shown through the results of the LVDT. When the resin is introduced into the piece, the graphs that the LVDT produce gradually rise. When the piece is fully wet-out, the graphs reach a maximum height and a steady state. This means that the same amount of resin that is being let in is being taken out. Once steady state is reached, the feed tube that provides the resin is clamped off and the vacuum pulls the excess resin out of the piece.

Having a perfect vacuum is very important. An ideal vacuum is 30” Hg. There are many places where leaks could exist. The vacuum pot must be tightly shut so that no air can leak in from the sides of the lid. In some cases, air that is between the clamp on the feed tube and the resin bucket will get into the piece as the resin follows. This air makes the piece fluctuate rapidly during the entire infusion. The LVDT is very effective in showing the rapid changes that the air causes.

Atmospheric pressure plays another role in the VARTM process. There is pressure pushing against the vacuum bag and pressure pushing against the bucket of resin. If the pressure is higher, the vacuum on the piece will be much higher. The atmospheric pressure pushes on the vacuum bag, causing more air to be pulled out by the vacuum pump.

Placing the vacuum and feed tubes in the correct locations can determine how quickly and effectively the resin flows into the preform. Feed tubes should not exceed the length of the preform. The tube should go in the front of the piece if it is the lab-made preform. For this type of piece, the coil tubing is used. Solectria panels require the feed tube (an omega channel) be positioned on top of the preform (see fig.1). This will prevent dry spots from occurring by forcing the resin to flow through the piece instead of race tracking on the sides. Vacuum tubing is coil tubing that has another tube inserted into it (fig. 2), which leads to the vacuum pot.

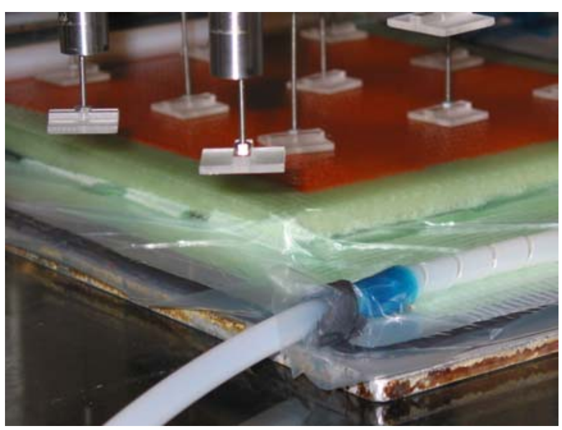


**Figure 2**-Vacuum tube in the VARTM process

A certain binder is used to hold the Solectria preforms together. Some of these binders mixed with the resin during infusion caused the piece to be discolored. This binder also causes the infusion process to take longer because it makes the preform denser.

The SCRIMP distribution medium must be positioned properly during the setup. It should be approximately an inch to two inches away from three sides of the preform with one side going under the feed tube (fig. 3). This permits the resin to travel onto the SCRIMP and on top of the piece so the infusion is faster and more even.

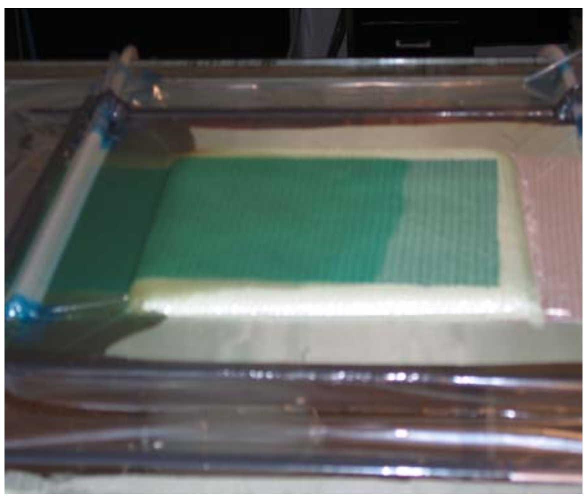


**Figure 3-** SCRIMP layer channeling resin

During infusion problems can occur that will affect the quality of the piece. If the coil tube from the vacuum becomes loose, it will spring back to normal and could seal any holes in which vacuum would be pulling. This would impede on the quality of the vacuum, making the infusion process last longer and weaken the compression that the bag puts on the piece. Also, if the tacky tape does not stay sealed to the steel plate, it can create holes for air to leak in. This could destroy the vacuum and any chance for a quality piece to form.

When the infusion process is completed, the piece must cure. Curing is the process in which the resin hardens. There are several ways that the piece can cure. It can either be left at room temperature for about 48 hours or, to speed up the process, it can be put into an oven. If the temperature of the oven is set too high, the sides of the piece will flare up and the entire piece will become less dense. This will offset the strength properties of the panel.

# Conclusion

In the VARTM process, there are many variables that can dramatically change the outcome of the composite piece. Setting the process up is the most important stage. It will determine whether or not a good quality piece will be formed. Based upon the changes that were made and the variables of the VARTM process it was determined that the process could be made more reliable and stable.

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